Agrilectric Power Incorporated

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Introduction

Agrilectric Power, Inc., began the project with objectives that included identifying potential markets, defining system requirements, and reviewing technical issues requiring resolution. In addition, the goals included evaluating the environmental concerns while assessing the projected costs and developing strategic partnerships required to finance and complete the business development. The technology is an extension and refinement of that used at Lake Charles, Louisiana, to generate electric power by using rice hulls as fuel with the knowledge and experience gained during the operation of the facility. The specific study involved a family of rice hull-fired power generation units (PGUs) that would be deployed in emerging markets.

By working with a Japanese manufacturer of rice milling equipment, the study identified the sizes of PGUs of 500 kW, 1500 kW, and 5000 kW sizes, which closely matched production of rice hulls and power requirements for the operation of three line sizes of rice milling equipment. Once these capacities were identified, the quantity of hulls produced and the power requirements for mill operations set, the actual design sizes of the generating units were known. A design for each size was made based on the PGU being sited near a rice mill of the proper size. The economics of sizes and costs of the boiler and turbine required the economic choice of steam conditions for the best combination. A review of the expected emissions projected compliance with the regulations of these types of emissions.

Price projections have been made for these units based on U.S. equipment supplies, and discussion with vendors in other countries have shown possible significant reductions of total costs. The market for these units appears to be primarily outside the United States. The protective tariffs placed on imported goods by many countries causes the equipment to be more economically viable when purchased in the country of final use. This progress of unit size identification and cost estimates for import to other countries with rice production are major advances in implementing a development strategy.

Potential Markets

The major market for this type of technology is outside the United States because of highly competitive fossil fuels, low power prices, and competing markets for rice hulls. The rice-producing areas in the United States can still dispose of rice hulls by landfilling when there is no market for the hulls such as bulk addition for animal feed. Changes in this capability that would increase the costs of disposal would increase the market potential for this technology.

Abroad, the primary rice-producing regions are Latin America, Southeast Asia, and the Pacific. Rice is also grown in parts of Egypt and Turkey, which could develop into market opportunity areas. In consideration of the current status of worldwide economies, the areas that appear to be prime, near-term market opportunities are Brazil, Uruguay, and Argentina. In Asia, Thailand, India, Malaysia, Indonesia, and China are the leading countries of market potential. The Philippines are also considered a high potential but, as with most countries, economic problems still impede full development.

The market for rice hull-fueled PGUs is thought to be small in terms of potential generation installed, but large in numbers of PGUs. The original estimate made at the beginning of the joint effort is shown in Table 1. This was based primarily in Asia. South America seems to be at least as large in potential.

Table 1. Original Estimate

Unit Size	500 kW	1.5 MW	5 MW
Potential Number	15 units	8 units	3 units

Table 2 lists the fuel available from a rice mill producing these hull quantities. The power consumption of the rice mill is based on the designs of the manufacturer.

Table 2. Fuel Available from Rice Mill

Unit Size	500 kW	1.5 MW	5 MW
Fuel Available	1 to 1.4 T/h	3 to 6 T/h	10 to 14 T/h
Total Output kWh	480-600	1400-1800	4800-6000
Auxiliary Use kWh	80-100	200-300	800-1000
Net Output kWh	400-500	1200-1500	4000-5000

Based on cost estimates of U.S. supplied equipment, Table 3 indicates the expected costs for a non-site specific site. Numerous factors are involved, which at this point are assumptions only. They can directly affect the final installed cost of the generating unit.

Table 3. Expected Unit Costs

Estimated Unit Cost	500 kW	1,500 kW	5 MW
First Unit Costs	$2,985/kW	$2,832/kW	$1,750/kW
Second Unit Costs	$2,835/kW	$2,690/kW	$1,663/kW

South America seems to be at least as large in potential. Further investigation in Brazil and China indicates that identifying manufacturers in countries that can produce the required equipment may reduce these costs. This does not address the concern of design confidentiality and the ability to control the release of design specifications to unauthorized parties.

System Design

The system design can burn rice hulls. Even though other fuels could be considered, the present effort is limited to the single fuel because the potential market is so large and applicable to so many areas of the world. The attached heat balance is for the 5000-kW design and shows all major equipment. The design significance is in the boiler and combustion system. The equipment outside this area is used in many installations around the world. The steam from the boiler is transported to the steam turbine where the energy is converted from mechanical to electrical in the generator. The spent steam is condensed back into water for pumping back to the boiler. The water from the cooling tower cools the condenser. The additional capability to use low-quality steam to dry rice or a parboiling of rice operation enhances the economics of this type of technology.

The rice hulls coming from the mill are ground by a hammermill and then transported to a storage or day bin. The feeders in the bottom of the bin control the amount of hulls or fuel being fed to the burners. As the feeder discharges the hulls, hot air is combined with the hulls in a venturi type device and transported to the burners. Two burners of equal capacity on the front of the boiler introduce the hulls into the furnaces. Because the hulls have been reduced in size, they are immediately combusted in the furnace while in suspension. There is no floor or grate in the furnace of the boiler. All combustion takes place before any ash falls from the gas stream. As the ash-laden gas flows through the system, hoppers at each device collect it. As the gas passes through the superheater, air heater, and economizer, its temperature decreases. When the gas enters the baghouse or fabric filter, the temperature is sufficiently low so that it will not harm the fabric bags. The gas passes through the cloth and the ash is collected on the outside of the bags and eventually falls into the hoppers for collection.

The ash formed by this process is a marketable product for various uses. Rice hulls combusted by other technologies may form a crystalline structure that is considered a respirable dust. In the amorphous form, the ash is considered benign. The ash produced by the suspension combustion is 99% amorphous. Uses include the steel industry for insulation material in the processing, filtration media, and combined with portland cement for a superior concrete. Ash from this type of unit will add income from the ash sales rather than being a disposal cost.

The status of the design is conceptually complete. Sizing and general arrangement of the systems were made for all three. Piping and instrument designs (electrical one lines) were developed and the control schemes were detailed for 5000 kW. A review for the site-specific requirements will be necessary when a particular installation is chosen. Minimal work on the details of the generating system will be required.

Table 4. Heat Rates

500-kW Heat Rate:	38,780 Btu/kWh or 9772 kg-Cal/kWh
1500-kW Heat Rate:	24,200 Btu/kWh or 6098 kg-Cal/kWh
5000-kW Heat Rate:	16,160 Btu/kWh or 4052 klg-Cal/kWh

Although other systems and arrangements afford better heat rates, the overall goal must remain prominent in performing this design. The object is to use rice hulls in the most efficient manner without producing by-products that create problems. Efficiencies can be enhanced in this type of combustion system but at the cost of manufacturing an ash, which can be considered a hazard. Experience in the field with rice millers shows that the capital cost of these system's the largest concern. Use of rice hulls allows less efficient consumption if the price is justifiable and no additional problems are created by their use.

The Phase 1 work continued development into three sizes of units that will fit the mill capacities of rice milling equipment sizes; future work will require continuing efforts to reduce the initial capital costs. The possible assistance in this effort will be pursuing manufacturers in countries such as Brazil and China. Qualifications of boiler manufacturers will require the most strenuous effort to ensure the quality, detail design capability, business credibility, warranty assurance, and product support.

Other major engineered equipment, although important to the success of the overall project, is less significant to the combustion/steam generation piece. Turbines, generators, condensers, pumps, feedwater heaters and the other equipment required is used in power plants with a great variety of fuels. Therefore, having greater variety of this type of equipment from several sources can ultimately reduce the overall costs of the project.

The expected environmental parameters are air emissions only and stated in Table 5. No significant differences are expected between unit sizes; therefore, applicable to all three designs. The particulate estimate is based on the assumption that a fabric filter will be used for control. Efficiencies of this device are matters of choice for particular locations and may not be included in the plant equipment. Other devices can be used with the penalty of additional emissions of particulate. If a market for this ash is developed, its recovery for sale may be an additional driving force to choose the more efficient collection device.

Table 5. Air Emissions

Oxides of Nitrogen – NO_x (lb/mmBtu)	0.05
Reactive Organic Compounds – ROC (lb/mmBtu)	0.001
Sulfur Dioxide – SO_2 (lb/mmBtu)	0.05
Carbon Monoxide – CO (lb/mmBtu)	0.159
Particulate - PM10 (gr/dscf)	0.01

Future Development

Agrilectric Power, Inc., is marketing the technology as we develop the details of the design. There have been unsuccessful attempts to identify additional projects in the United States. The deregulation of the utility industry, combined with the abundance of natural gas in the rice-growing regions and additional markets developing for rice hulls, severely limit the capability of additional generation with rice hulls. In some regions, additional environmental compliance would open the reexamination of the potential. Deregulation by some states has included a renewable generation portfolio, which could bring about further development.

International development continues to be the most promising for this technology. Project development has been ongoing in South America, particularly Brazil. The rice industry in Brazil is strong and continues to grow in spite of recent economic problems. Manufacturers have been surveyed and some have been given the opportunity to demonstrate capability. The import duties on U.S. equipment is 25%, imposing a severe pricing disadvantage. Sources for all major equipment required for the power generating unit have been identified in Brazil with confidence that the standards used would provide a reliable system for this application.

Initial discussions have begun with manufacturers in China. Preliminary investigation indicated that the Chinese do not have detail design capability in the boiler manufacturer's organization. It was thought that the detailed design would have to be performed by design institutes that are fragmented into specialties and no one organization would be able to perform an overall design. This capability is a requirement because of the warranty serviceability requirements. Discussions with the manufacturers proved that they do have all the required capabilities and are very interested in pursuing this type of business arrangement. The design for the three units will have to be modified to coordinate with the turbine manufacturers in China who have chosen a different set of steam conditions for the common usage in small power generating plants.

Another effort to assemble a project in South America was made earlier this year when an engineering/construction company was asked for a cost proposal. The requirements of the project were to use U.S. equipment and package it into modules on the Texas Gulf coast. The equipment would then be shipped to South America for assembly on the plant site. This too, proved to be too expensive.

Future marketing and development efforts will continue to pursue international markets in the regions discussed earlier. The design concept discussed here provides a starting place for discussions and a realistic look at costs for this technology, but much work remains to reduce the costs to complete the marketing process. Agrilectric Power, Inc., and its partner Satake Corporation will continue to work with the Chinese as that method appears to be the most likely road to success.